perimeter was very rough. This change in the variation of c with relation to the slope was found to depend upon the hydraulic radius being greater or less than 3·281 feet; so that c becomes independent of the change in slope when R approximates to this value, though the actual value of R at which the modification occurs varies with the degree of roughness of the channel. This result is attributed to the conflicting currents and eddies in large rivers having irregular beds, or in small channels with very rough beds, which are intensified by an increase in the slope; whereas, in small streams flowing in confined channels with smooth beds, an increased velocity tends to dissipate retarding lateral movements. A preliminary form adopted for the value of c was $\dfrac{a + \dfrac{l}{n}}{1 + \dfrac{an}{\sqrt{R}}}$, where $a + \dfrac{l}{n}$ replaces y in the original formula, and $an = x$, or $x = ny - l$, in which a is a constant with value 41·66 in English measures; l is another constant, equal to $\sqrt{R}$ when R has the special value 3·281 referred to above, and therefore 1·811; and n is the coefficient of roughness, varying, according to the state of the channel, from 0·009 to 0·040. The above value of c suffices for the flow in pipes and other small channels with steep slopes, owing to the small influence of a variation of slope on the coefficient c in such cases; but for ordinary channels allowance has to be made for variations in slope, necessitating the introduction of another variable factor into the expression for c. The final shape given to the value of c by Messrs. Ganguillet and Kutter, in their general formula, was $\dfrac{a + \dfrac{l}{n} + \dfrac{m}{S}}{1 + \left(a + \dfrac{m}{S}\right)\dfrac{n}{\sqrt{R}}}$, where $m = 0{\cdot}0028075$, for English measures, is a constant of a hyperbola employed in constructing the formula. The general formula, accordingly, became, for English measures—

$$V = \frac{\dfrac{1{\cdot}811}{n} + 41{\cdot}6 + \dfrac{0{\cdot}00281}{S}}{1 + \left(41{\cdot}6 + \dfrac{0{\cdot}00281}{S}\right)\dfrac{n}{\sqrt{R}}}\sqrt{RS},$$

where V is the mean velocity in feet per second, which multiplied by the cross-section would give the discharge in cubic feet per second, and S is the actual slope.

The main interest of the book consists in the clear exposition of the several steps by which the formula was reached; and even if at some future time, by the aid of fresh observations and more accurate experiments, the formula should be superseded by a more comprehensive and exact one, the merit of this work as an elaborate scientific investigation for a general empirical formula must always remain; and the book would deserve to be consulted on this ground alone. The formula depends entirely upon the exactness of the observations upon which it has been based. Mr. Révy has questioned the accuracy of the Mississippi experiments, owing to the use of double floats; and if fresh investigations should establish the inaccuracy of any of the observations made use of, or if further experiments should extend the scope of the inquiry, or bring new facts to light, a modified formula will be required. The authors, however, of the formula do not regard it as final or complete, nor do they claim for it any mathematical precision; they only consider that it agrees more closely than any previous formula with the results of recorded observations. The formula has naturally been objected to on account of its complicated appearance; but the variation due to change of slope renders this inevitable; and it has been seen that a simpler formula may be adopted for pipes, and small channels with steep slopes; and, moreover, graphical methods and tables might simplify the calculations. At the close of last year, Mr. Robert Manning, Engineer to the Board of Works in Dublin, presented a new formula to the Institution of Civil Engineers of Ireland, which, in its general form, is hardly less complicated than that of Messrs. Ganguillet and Kutter. This formula is

$$V = n\sqrt{Sg}\left\{R^{\frac{1}{2}} + \frac{0{\cdot}22}{m^{\frac{1}{2}}}(R - 0{\cdot}15m)\right\},$$

where n is the coefficient of roughness, g the force of gravity, and m the height of the barometric column of mercury. Mr. Manning puts it forward as simpler and better than the other, and claims for it, in a simplified form, a closer approximation to the mean of the results of seven of the best known formulæ than any other. Actual observations, however, form a surer basis upon which to establish a general formula than the results of previous formulæ; and it is upon a close concordance with very varied and accurate observations that any general formula must claim acceptance. Whatever position may in the future be assigned to the formula of Messrs. Ganguillet and Kutter, their work marks a notable step in advance, and must rank with the researches of Messrs. Darcy and Bazin, and Messrs. Humphreys and Abbot, as a record of important hydraulic investigations; and the translators have performed a valuable service in placing clearly before English readers the successive steps by which this general formula has been established.

THE COMPASS ON BOARD.

Der Kompass an Bord: Ein Handbuch für Führer von eisernen Schiffen. Herausgegeben von der Direktion der Deutschen Seewarte. (Hamburg: L. Friederichsen and Co., 1889.)

THE important subject of the magnetism of iron ships and the resulting deviations of their compasses, has, during the last fifty years, received marked attention in England from eminent men of science, attended with most valuable results for the safe navigation of our Royal and mercantile navies.

During the last thirteen years this same subject has been one of continuous inquiry at the German Naval Observatory in Hamburg, and papers have been published from time to time in the annual report of that institution, showing what had been accomplished. Combining the results of this work with those obtained from the extensive literature chiefly produced in England, Dr. Neumayer, the Director of the Observatory, has compiled the present work for the use of officers commanding the iron ships of the German mercantile navy.

Of the six chapters into which the work is divided, the first is devoted to information on the magnetism of iron

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and steel, terrestrial magnetism, and the means of obtaining the three magnetic elements.

In the second chapter, the various modern forms of the mariner's compass, and instruments for adjusting compasses without sights, are described with illustrations. There is much here which should be of value to commanders of ships anxious to know as much as possible of their best friend in navigation.

It is, however, to be regretted that in some particulars both text and illustrations belong to the past, for in Fig. 38 an imperfect idea is given of Sir W. Thomson's compass. The drawing was correct for 1877, but important improvements were made ten years ago in the substitution of the wire grummet suspension for india-rubber, a change attended with marked success in vessels propelled and severely shaken by powerful engines; also, in 1881, the adoption of a total reflection prism in the azimuth mirror instead of an ordinary piece of looking-glass.

Prominence is given to the Hechelmann compass card, which is intended to combine the principles of the Thomson card (which consist chiefly of a long period of oscillation and great lightness), with a much greater magnetic moment in the Thomson-Hechelmann card, as it may be termed. The chief difference in these cards lies in the arrangement of the needles, Hechelmann's idea being to suspend more powerful needles than Thomson's near the circumference, thus bringing the weight as far as possible from the centre of the card to produce a slow period.

In bringing powerful needles so near the circumference, it is easy to see that something has been lost by Hechelmann when the quadrantal deviation is to be corrected as it should be—a correction so perfectly accomplished by Thomson. The greater weight of the card, too, tends to increase friction at the cap and pivot. Under these considerations the Thomson-Hechelmann card can hardly be considered equal to the modern Thomson.

In the next chapter, which treats of the magnetism of ships and the resulting deviation, it is satisfactory to find that the different kinds of magnetism which careful investigation has shown to exist in modern vessels are specially mentioned. These are—

(1) Permanent magnetism.
(2) Sub-permanent (termed also retentive) magnetism.
(5) Transient magnetism.

These definitions are accompanied by a footnote stating that in the English text-books on deviation no difference is made between permanent and sub-permanent magnetism, but that the two are combined under the expression sub-permanent. This is perhaps rather hard upon some English books, where, by careful reading, it will be found that the distinction is really made, but, it must be confessed, with a want of that clearness of division which is important to sound knowledge. Readers of the papers published by the Royal Society, and more recently by the Royal United Service Institution, will find that the division of a ship's magnetism into the three kinds mentioned above is strongly insisted upon.

A complete analysis of the deviations of any given compass in a ship, and of the changes which take place on a change of latitude, is necessary before a satisfactory compensation of the deviation by magnets and soft iron can be made. In the "Compass on Board," this analysis has a chapter devoted to it, containing information which should be of value both to the captains of ships and compass adjusters. It is illustrated by many examples.

Values of the coefficients v and v', representing the temporary deviation caused by running on a given course for some days, are given for a number of vessels of different types, steam and sailing. They clearly show the navigator of a new ship the need of caution when altering course, and some idea of the amount of change of deviation he may expect; whilst it should be understood that no careful seaman would fail to learn and note the peculiarities of the iron affecting his ship's compasses from personal observation under the varied circumstances experienced during each voyage.

A corrector for the deviation caused by sub-permanent magnetism has yet to be discovered.

Taking a general view of this book, it may be described as calculated to provide good practical information for the officers of the German mercantile navy, as well as a certain amount of a theoretical nature for those inclined to learn something of a ship's magnetism from a higher standpoint.

The maps of the three magnetic elements provided at the end of the book are given for the epoch 1885, and on a larger scale than those usually provided in hand-books. The accompanying map of values of the secular change is somewhat open to criticism as regards the figures recorded in the Red Sea, Bombay, East Indies, and Australia. This, however, will not prove of any detriment to safety in practical navigation.

The difficulties connected with the compass in warships, with their armoured deck, thickly-plated sides, and conning-towers, are not treated of, and their officers must look elsewhere for the special information they require; still, there is much to be found in this book that will serve their purpose.

OUR BOOK SHELF.

Library Reference Atlas of the World. By John Bartholomew, F.R.G.S. (London: Macmillan and Co., 1890.)

THE recognition of the intimate connection that exists between physiography and geography is made very manifest, in all the atlases published during the last few years, by the insertion of maps indicating the physical features of the earth's surface.

We are in an eminently utilitarian age, and a collection of maps, to meet the requirements of the day, must serve more purposes than that of a mere index to the positions of places; it must represent the most permanent features of importance in commercial geography, and the distribution of commodities as explained by the sciences of physics, geology, meteorology, biology, &c., or collectively by physiography. The elegant work before us satisfies all these requirements, it is as complete as it is a trustworthy atlas of modern geography, and will be equally appreciated by the student, the business man, and the general reader.

The atlas contains 84 maps, and amongst them we find plates delineating drainage areas, ocean currents, prevailing winds, rainfall, temperature, climate, and commercial features. A characteristic of the collection is the large number of maps that have been devoted to the British Empire, eighteen plates being given of the United Kingdom alone. India is completed in eight plates, the Dominion of Canada is very completely represented in seven plates, and the mapping of all the British possessions

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